

154 ✓

Task Force on Oil Spill Preparedness
Technical Report Number 92-01

**Evaluation of the Foxtail
Skimmer in Broken Ice**



CANADIAN PETROLEUM ASSOCIATION

TFOSP

This report and the information contained within is the result of one of the many programs identified by the Task Force on Oil Spill Preparedness (TFOSP) in the 1990 Implementation Plan. With leadership from the Canadian Petroleum Association (CPA), the upstream petroleum industry carried out specific projects aimed at improving spill preparedness, with respect to Canada's offshore regions. The CPA and industry undertook initiatives in the areas of Planning and Prevention, Equipment and Training and Research & Development.

For additional copies of this report, or for a listing of other TFOSP reports, please contact the Publications department, Canadian Petroleum Association in Calgary, Alberta, Canada.

**EVALUATION
OF THE
FOXTAIL SKIMMER
IN
BROKEN ICE**

PREPARED FOR

CANADIAN PETROLEUM ASSOCIATION

AND

**ALASKA CLEAN SEAS
CANADIAN COAST GUARD
COOK INLET SPILL PREVENTION & RESPONSE INC.
ENVIRONMENT CANADA
MARINE SPILL RESPONSE CORPORATION**

BY

COUNTERSPIL RESEARCH INC.

JANUARY 1992

FOREWORD

The performance of the Foxtail Skimmer was assessed in a lined pit with North Slope Crude Oil and diesel at the Tesoro Refinery near Kenai, Alaska December 2-6, 1991 under the sponsorship of the Canadian Petroleum Association, with participation by the following organizations:

- Cook Inlet Spill Prevention & Response Inc. (CISPRI)
- Alaska Clean Seas
- Environment Canada
- Marine Spill Response Corporation
- Canadian Coast Guard

Mr. Nick Vanderkooy of Canadian Marine Drilling Limited and Mr. Bruce MacKenzie of Alaska Clean Seas initially planned and facilitated the Foxtail tests, and were assisted in program management by Mr. Peter Devenis of the Canadian Petroleum Association.

CISPRI, under the supervision of Mr. Burl Wescott - Prevention/Planning/Development Coordinator, provided a work crew to undertake preparation of the test pit, distribution and disposal of test oils, skimmer operation, and ancillary tasks.

Northern Test Lab conducted analytical work on collected oil samples.

Mr. Laurie Solsberg of Counterspil Research Inc. developed a test protocol for the program and oversaw data collection and reporting. Reviewers associated with, or otherwise requested by, the sponsoring organizations provided valuable input to the final report.

TABLE OF CONTENTS

	<u>Page</u>
FOREWORD	i
1.0 INTRODUCTION	1
2.0 EVALUATION PARAMETERS	3
3.0 METHODOLOGY	5
4.0 TEST DATA	6
5.0 DISCUSSION OF RESULTS	10
6.0 OPERATIONAL ASPECTS	11
7.0 CONCLUSIONS AND RECOMMENDATIONS	13
APPENDIX	14

1.0 INTRODUCTION

BACKGROUND

The Foxtail V.A.B. 8-14 Oil Skimmer was evaluated in December 1991 in Kenai, Alaska to provide insights into its oil recovery capability in broken ice. Like its smaller counterpart, the V.A.B. 4-9 originally slated for testing, the skimmer is a vertically-oriented rope mop device which is deployed from a crane. It is fabricated by H. Henriksen Mek. Versted AS of Tonsberg, Norway and marketed by Nor-Marine of Oslo, Norway and Scan Pacific Enterprises, Inc. of Mukilteo, Washington, USA. Objectives of this test program were:

- To measure skimmer performance in North Slope Crude Oil and diesel, and record associated machine settings, oil characteristics and ambient conditions.
- To identify operational deficiencies and suggest modifications which have the potential to improve skimming.
- To make recommendations for rigging details and procedures required for sea trials of a Foxtail Skimmer in conditions of broken ice.

EQUIPMENT DESCRIPTION

The V.A.B. 8-14 Foxtail Skimmer (see Figure 1) owned by the Cook Inlet Spill Prevention & Response Inc. (CISPRI) was utilized for the tests. Its specifications are as follows:

Skimmer	Weight of Empty Unit	900 kg	(1,984 lbs)
	Weight of Operating Unit	1 400 kg	(3,086 lbs)
	Outside Dimensions	2.2 x 2.4 x 1.1 m	(7.2' x 7.9' x 3.6')
	Number of Bands	8	
	Length of Band	15 m	(49')
	Band Width	36 cm	(14")
	Hydraulic Pressure	150 - 240 bar	(2,175 - 3,480 psi)
Pump	Type	axial screw	
	Weight	450 kg	(992 lbs)
	Hydraulic Pressure	150 - 210 bar	(2,175 - 3,045 psi)
	Connection	12.7 cm	(5")

TEST FACILITIES

A test pit 25 x 50 x 4 ft (8 x 15 x 1.2 m) was excavated at the Tesoro Refinery, lined with a synthetic membrane and filled with Cook Inlet water. In addition to the crane utilized to deploy the skimmer, four 200 gallon (760 L) fish totes were used as oil distribution and collection vessels. Larger 2 - 3,000 gallon (8 - 11 000 L) Fast Tanks were later added for storage along with a 600 gallon (2 270 L) demarcated separator with bottom drain which enabled quantification of recovered oil and water phases. Various pumps and hoses provided transfer capability. Figure 2 and Plate 1 show the layout of testing facilities.

FIGURE 1 FOXTAIL SKIMMER

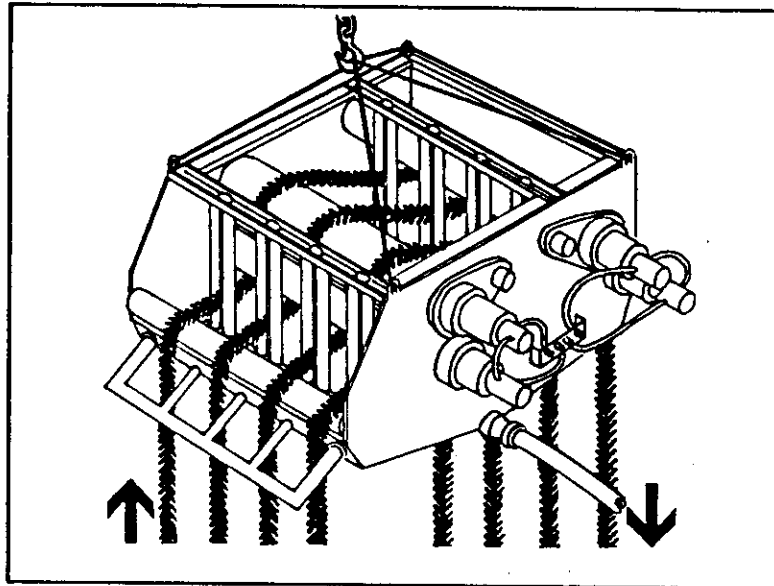
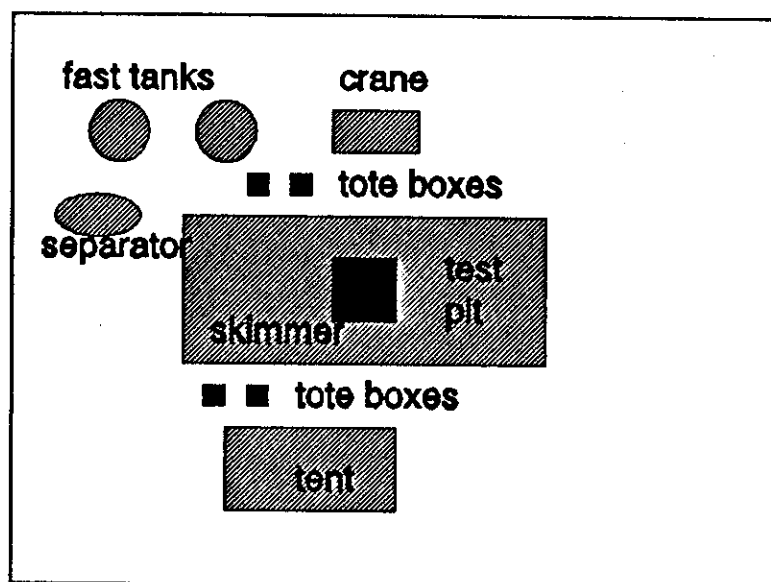


FIGURE 2 TEST LAYOUT



2.0 EVALUATION PARAMETERS

A testing strategy was devised to isolate the effects of individual parameters on skimming in order to optimize machine performance. Two categories of test variables were addressed:

INDEPENDENT variables, the parameters varied during testing:

- (a) TEST TANK CONDITIONS
- (b) SKIMMER ADJUSTMENTS

DEPENDENT variables, the resulting skimmer performance achieved for each set of independent test variable values:

- (c) MEASURED TEST DATA
- (d) CALCULATED TEST DATA

(a) TEST TANK CONDITIONS

Tank conditions involved three parameters: (1) oil type, (2) slick thickness and (3) ice cover. Since the tests were conducted in calm water, wave conditions were not measured.

Oil Type

Tests were conducted with North Slope Crude Oil and diesel. The crude oil was allowed to age during the tests, i.e. the oil used in previous tests was applied to subsequent evaluations. The test oils had the following properties:

	<u>Specific Gravity</u>	<u>Viscosity (cSt)</u>	<u>Pour Point (°F/°C)</u>
Crude	0.89 to 0.97	82 - 1,340	-5/-21 to 27/-3
Diesel	0.81	3	< 60/-51

Slick Thickness

A slick thickness of 0.2" (5 mm) was originally planned for all tests but ranged up to 0.3" (7-8 mm) and 0.4" (10 mm) to ensure sufficient oil presentation to the mops. Thickness was estimated by dividing the volume of oil distributed for testing by the area containing it. Each 55 gallons (208 L) of oil initially covers about 450 ft² (42 m²) to a depth of 0.2" (5 mm). A portion of the test pit was isolated to achieve the desired thicknesses which could be directly measured for diesel using a barrel sampler. Water-detecting paste and an additional tube sampler were also tried but coating was a problem in the crude oil.

Ice Cover

For tests in broken ice, approximately 4/10ths ice cover was utilized consisting of pieces ranging from 6" (15 cm) to 2-3' (0.6-1 m) across and 4-9" (10-23 cm) in thickness.

(b) SKIMMER ADJUSTMENTS

Skimmer adjustments comprised the basis for the tests:

- Mop speed (roller pressure was adjusted once)
- Length of mop contacting water
- Repositioning or sweeping of rope mop during testing

(c) MEASURED TEST DATA

Data measured or recorded for each test run are summarized in Table 1 and presented in detail in the Appendix. These included:

- Volume of apparent oil and water phases collected
- Time for liquid recovery (usually 15 minutes)
- Observations re: mop response, mop/wringer performance, safety

(d) CALCULATED TEST DATA

Measurement of skimmer performance was based on two computed assessment parameters:

Recovery Efficiency (RE): Percent oil in the recovered oil/water mixture.

Oil Recovery Rate (ORR): The oil collection rate net of recovered water.

Other determinations were made during the test program to document results. Samples of the test oil and liquid recovered by the skimmer were collected and tested by laboratory analyses for the following:

- Specific Gravity
- Viscosity (at three temperatures)
- Pour Point
- Interfacial Tension (1. oil and water 2. oil and air)
- Water Content

Environmental conditions were also recorded during each test:

- Air temperature
- Water temperature at the oil/water interface
- Wind speed
- Wind direction
- Weather conditions during test run such as precipitation, cloud cover, etc.

Test data summaries were prepared for each evaluation run and are presented in the Appendix. The summaries indicate the environmental conditions, measured data, and the computed oil recovery rate.

3.0 METHODOLOGY

Initial shakedown runs allowed personnel to familiarize themselves with operation of the complete system and to "prime" the polypropylene bands with oil. This also facilitated the selection of a range of rope mop speeds, rope mop lengths contacting the water, and collected liquid storage and transfer needs for the tests. A platform was arranged which could be lifted into place over the test pit and from which samples could be taken.

Day No.1 One day was required for setup and trial runs. Measurements were also taken of hydrocarbon concentrations in air to ensure the crude oil vapours did not present health or safety hazards.

Following the initial shakedown runs, testing was conducted in the following order:

OPEN WATER TESTING

Day No.2 Crude oil, allowed to age during the course of the tests, was presented to the skimmer for three mop speeds and two rope mop lengths contacting the water.
Test Series A Due to the time required to arrange for each test, replication of each setting was not pursued. Slick thickness of 0.2" (5 mm) and 0.3' (7-8 mm) were used.

Test Series B Tests in fresh crude were then conducted at two selected speeds and mop lengths in water. Slick thickness was doubled at the request of the manufacturer to 0.4" (10 mm).

Day No.3 Cleaning and preparation of the pit was undertaken to allow testing in diesel.
Test Series C Again, this involved tests at two mop speeds and two mop lengths in slick thicknesses of 0.2" and 0.3" (5 and 7-8 mm). A 600 gallon (2 270 L) oil/water separator was acquired and used to accurately determine apparent collected oil and water phases.

TESTING IN BROKEN ICE

Day No.4 Crude was distributed in broken ice and allowed to age during testing. Again two rope mop speeds and two rope mop lengths in water were selected for study. After the first stationary run, the Foxtail was swept through the test pit for the remaining five runs. Hot water was applied via an 8-nozzle spray arm supplied by the manufacturer in the final trial to investigate its effect on recovering aged crude. Initial slick thickness was 0.4" (10 mm) for all tests.

Day No.5 Aged crude from all previous tests was presented to the skimmer. Mop length and speed were each tried at two settings and hot water added again, this time at the slower mop speed, to determine if improved oil recovery would result.
Test Series E One final run was conducted to replicate the first run in ice conducted when the mop had been held stationary.

4.0 TEST DATA

Numerical test data, presented in Table 1, are summarized in this section and discussed further in Section 5.0. Skimmer construction and operation are reviewed in Section 6.0

TEST SERIES A & B

Test Series A and B showed that reducing mop speed resulted in a corresponding decrease in total recovered liquid (see Figure 3). While aging the crude did not affect the total liquid recovered, recovery rate increased with increasing viscosity. During the shakedown runs and A tests, changing mop height did not alter total liquid recovered. Volume peaked at 400 gal/15 minutes (6.1 m³/h). At higher mop speeds >1.25'/s (0.4 m/s), excessive liquid was seen to be spraying from the mops prior to their entry into the wringer/pulley assembly.

Decanting water was not possible during tests at 1'/s (0.3 m/s) and estimates only were made of the Oil Recovery Rate since it was assumed that a uniform emulsion comprised the collected liquid. (This was not likely the case.) However, in the runs at the lower speeds and with very viscous oil, the small volume of oil collected versus water was clearly evident. The tests confirmed the importance of concentrating oil with a boom in substantial thicknesses in order for the Foxtail to function effectively. Otherwise, the water cleared where the mops contacted the thin slicks and recovery included significant water uptake.

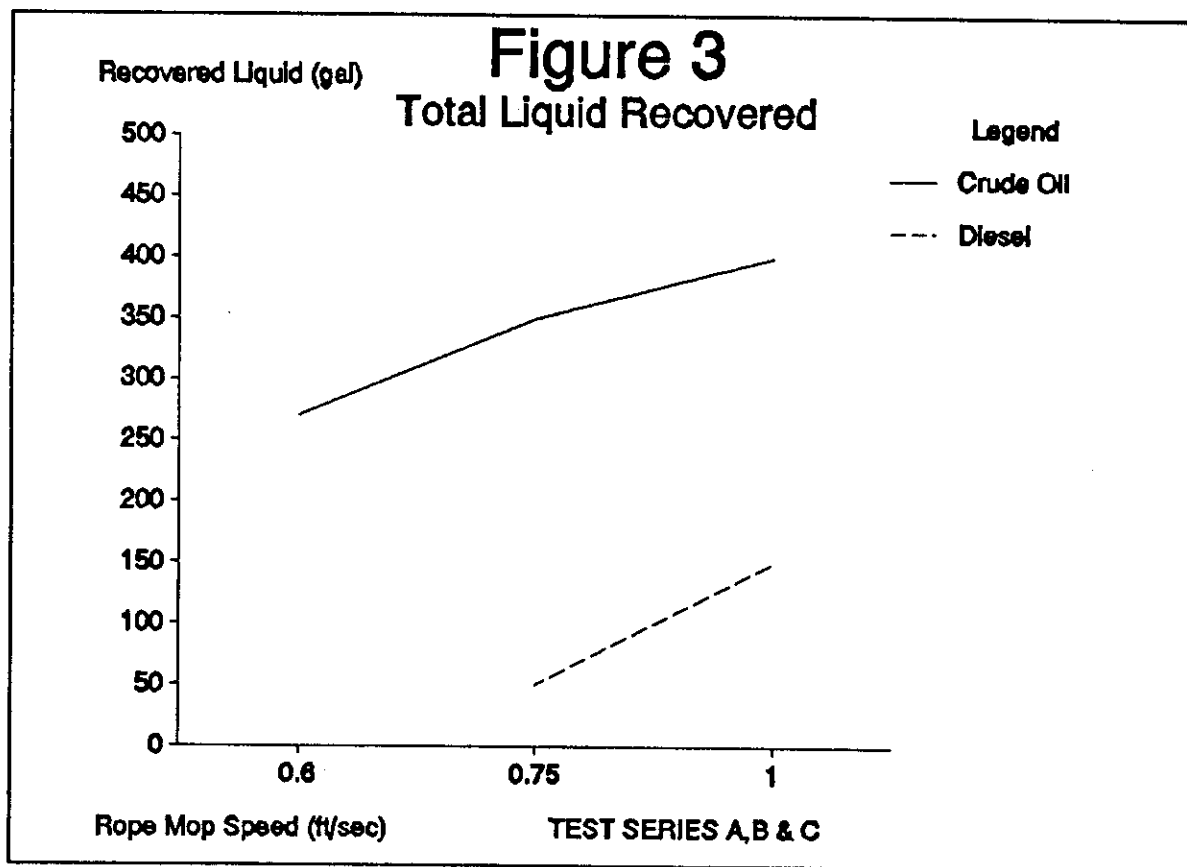


TABLE 1 TEST DATA SUMMARY

OIL PROPERTIES			ROPE MOP			RECOVERY		
Pour Pt (°F/°C)	Visc (cSt)	Thick ("mm)	Speed (ft/s)	Length (ft)	Tot Liq (gal)	App Oil (gal/%)	Oil (gal/%)	Water (gal/%)
<u>TEST SERIES A - Open Water; Crude allowed to age during test</u>								
25/-04	949	.2/5	1	6	400	237/59	--	163/41
27/-03	931	.2/5	1	12	400	251/63	--	149/37
29/-02	1,340	.3/7-8	.75	6	350	75/21	50/14	300/86
25/-04	972	.3/7-8	.6	6	270	20/7	11/04	259/96
<u>TEST SERIES B - Open Water; Fresh Crude</u>								
13/-11	299	.4/10	1	6	400	360/90	181/45	219/55
13/-11	286	.4/10	.75	6	350	207/59	--	143/41
<u>TEST SERIES C - Open Water; Diesel</u>								
-60/-51	3	.2/4	1	6	50	25/50	06/12	44/88
-60/-51	3	.3/7-8	.75	6	100	50/50	38/38	62/62 diesel/crude
-60/-51	-	.3/7-8	.75	18	100	15/15	--	85/85
-60/-51	5	.3/7-8	.75	18	150	40/27	14/09	136/91
<u>TEST SERIES D - 4/10ths Ice Cover; Crude allowed to age during test</u>								
-60/-51	7	.4/10	1	6	150	80/53	45/30	105/70 stationary
01/-17	179	.4/10	1	18	320	200/63	79/25	241/75
10/-12	316	.4/10	.75	18	250	125/50	64/43	186/57
12/-11	421	.4/10	.75	6	200	50/35	22/11	177/89
15/-09	1,111	.4/10	1	18	450	170/38	57/13	393/87
17/-08	851	.4/10	1	18	520	120/23	54/10	466/90 hot water
<u>TEST SERIES E - 4/10ths Ice Cover; Aged crude from previous tests</u>								
20/-07	944	.4/10	.75	18	270	100/37	41/15	229/85
20/-07	950	.4/10	.75	18	550	110/20	69/13	481/87 hot water
25/-04	1,469	.4/10	1	6	420	200/48	84/20	336/80

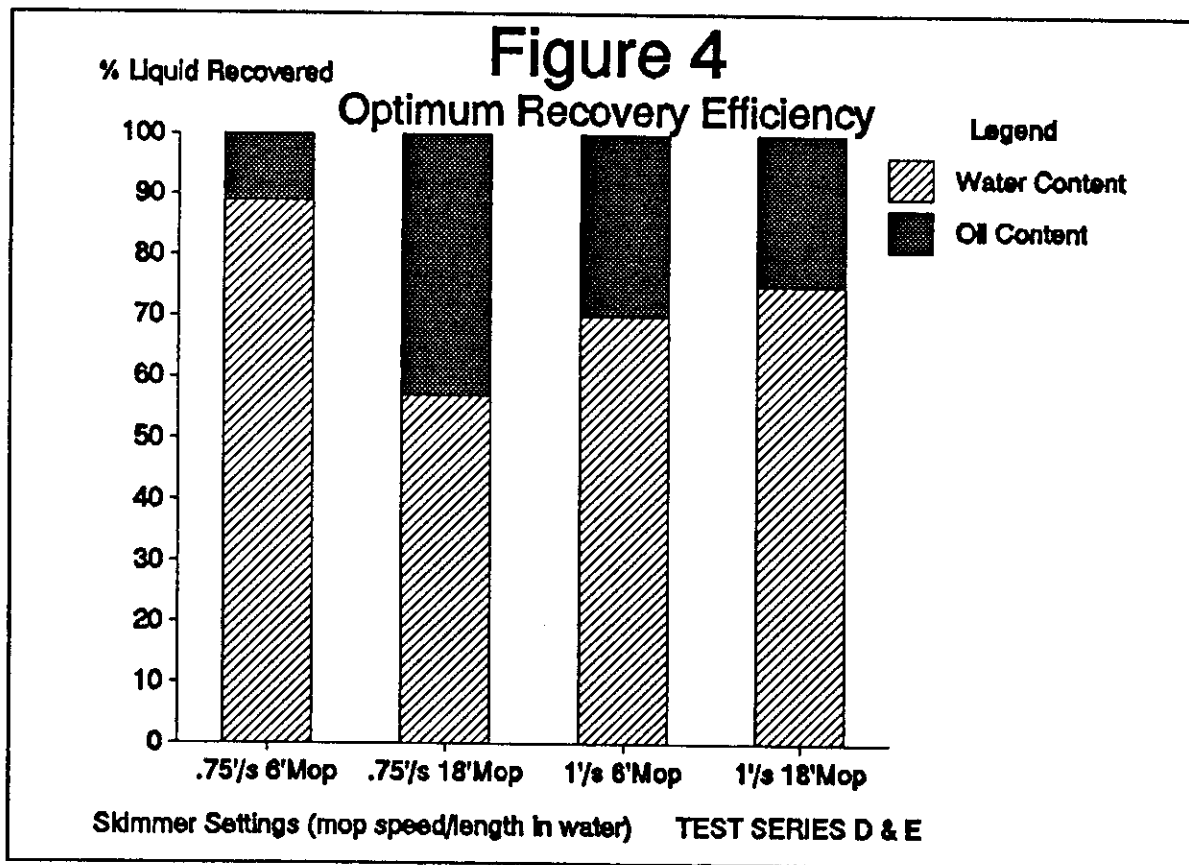
TEST SERIES C

Tests of the Foxtail in diesel produced lower values of total liquid recovered than the Series A and B crude oil trials (see also Figure 3). In one test, crude from previous testing was collected due to the solvent action of the diesel. Tests in diesel were discontinued due to the low Oil Recovery Rates 0.6-2.5 gpm (2-10 L/min). Recovery Efficiency reached 38% in the test in which a diesel/crude mix was skimmed.

Decanting water was begun during this test series and accurate determinations were then possible of the oil and water phases collected and the Oil Recovery Rate.

TEST SERIES D

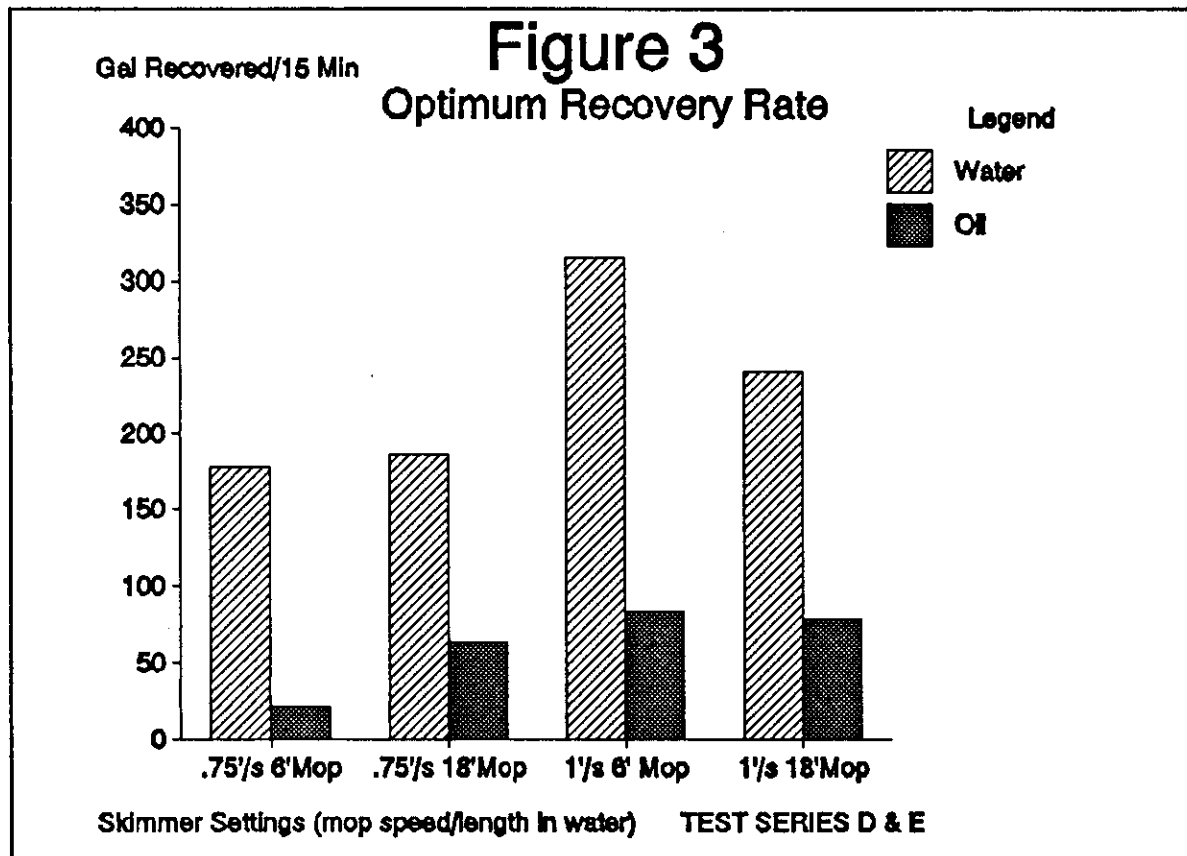
The Foxtail was tested in broken ice. This test series again showed the correlation between total liquid recovered and mop speed, and yielded the highest Recovery Efficiencies of all tests (depicted in Figure 4). The optimum value was determined for the trial run with 18' (5.5 m) of mop in the water at a speed of 0.75'/s (0.2 m/s). Generally, it was found that as viscosity increased, initial oil recovery was much faster. As in Test Series A, once the oil viscosity reached a certain level (in excess of 1,000 cSt), a reduced percentage of oil was apparent in the collected liquid. Highest Oil Recovery Rate was 79 gal/15 min or 1.2 m³/h.



Introducing hot water to enhance mop wringing, while not increasing the amount of oil recovered, substantially added to the volume of water recovered. The lower oil content was also due to matting of the mops as the aged oil clung to them and prevented further pickup. Recovery Efficiency was 10% and 13% for the two runs with hot water (see Table 1).

TEST SERIES E

Aged crude from previous crude tests was presented to the Foxtail with and without high pressure hot water. These trials again demonstrated the increase in volume caused by the introduction of the hot water but with some increase in oil uptake. A run carried out at 1'/s (0.3 m/s) -- without hot water -- with 6' (1.8 m) of mop in the water resulted in the highest volume of oil recovered during the tests: Oil Recovery Rate = 84 gal per 15 min or 1.3 m³/h. It also corresponded with a relatively high oil viscosity and some fluffing of the mops due to the previously applied hot water. Figure 5 depicts data obtained in Test Series D and E.



ENVIRONMENTAL CONDITIONS

Although there were significant periods of snow during the tests, the weather was relatively mild, with air temperature generally varying between 30°F (-1°C) and 34°F (1°C) and water temperature relatively constant at 32°F (0°C). Wind speed was estimated at 0 - 10 knots (0 - 5 m/s) throughout the testing period.

5.0 DISCUSSION OF RESULTS

The evaluations demonstrated that the Foxtail Skimmer operates optimally in thicker oil slicks of mid-viscosity (100 - 700 cSt) oil within a relatively narrow range of mop speeds of the order of 0.75 to 1'/s (0.2 - 0.3 m/s). At higher speeds, water pickup is evident as well as excessive spray and overall inefficiency of operation.

The rope mops pick up large volumes of water if they are deployed in relatively thin slicks and contact the underlying water phase. This points to the importance of containing and concentrating slicks for most efficient use of the Foxtail Skimmer. Higher Recovery Efficiency is expected when the skimmer is deployed in slicks of several inches (>4-5 cm).

The length of rope mop in the water appears to have less effect on Oil Recovery Rate and Oil Content than does oil viscosity. That is, the skimmer can be operated with 6' or 18' (1.8 or 5.5 m) of rope mop in the water and performance is comparable for any given oil viscosity. In ice, 6' (1.8 m) of rope mop could be readily made to "walk" across the oil and ice so that rate of forward advance matched the rope mop speed. The rope mop did not tangle in ice when 18' (5.5 m) was deployed; however, entanglement is possible in large, moving floes with higher edges. The latter represents a situation in which the skimmer might be used to recover oil because it can be so readily positioned.

Although the testing involved timed trials of 15 minutes each so that a common base was established, it was observed that for the mid-range of crude viscosities tested, most oil pickup occurred in the first 5 or so minutes of operation. Thereafter, Recovery Efficiency and Rate decreased in the remaining thin slick as water uptake prevailed.

The skimmer was observed to recover oil more effectively when advanced in the same direction as the mop travel, i.e. downward moving side. When moved in the opposite direction, ice pieces were pushed away from the skimmer along with oil. There is obvious merit in sweeping the mops rather than keeping them stationary as slicks are removed (run C-1 versus C-2). In the thinner slicks, the inside six mops play a minor role in pickup as compared with the outer two mops. (Use of the two and four band Foxtail Skimmers were discussed as possibly being more efficiently used in sweeping slicks.)

At viscosities exceeding 1,000 cSt or so, the rope mops tended to mat and recovery rate was reduced. The Foxtail did not recover diesel (0 - 5 cSt) at significant rates. Hot water at high pressure [150°F (66°C) @ 750 psi (5170 kPa)] introduced via a nozzle over each mop prior to the wringer did not result in increased Oil Recovery Rate but did add substantially (over 100 gal or 380 L per 15 min) to the water recovered.

Overall, the testing program provided the opportunity of identifying trends in the performance of the Foxtail system such as the correlation between recovery rate and mop speed and oil viscosity. The evaluations also indicated the usefulness of vertical rope mops in picking up oil in ice and the total liquid recovery rate that can generally be expected.

6.0 OPERATIONAL ASPECTS

Observations were made during testing on skimmer components and deployment:

CONSTRUCTION

The Foxtail is fabricated from several different metals including aluminum sump and guide rollers, cast iron motors and fittings, mild steel hydraulics and stainless connectors. Some electrochemical or corrosive action on the hydraulic fittings and smaller fasteners has already occurred although this is minor and should not cause an immediate problem.

FITTINGS

Pump couplings and hose connections were of European design. The pump connectors were changed by CISPRI to Camlock quick-connect fittings so that hook-up with additional hose is possible. Hydraulic fittings also required conversion to North American hardware.

WRINGER MECHANISM

The wringer rollers were able to continue to operate throughout the entire test period without malfunction. Substantial liquid containing both oil and water falls from the mop prior to its being wrung. This was due in part to the vertical guide rollers which contact the mops as well as the first guide roller over which the mops travel as they enter the skimming head. The manufacturer discussed the possibility of enlarging the roller so that the wringing effect is less pronounced. Repositioning the guide rollers was also noted so that these would not squeeze the mops.

Ice buildup occurred at ambient temperatures just slightly under freezing 32 to 28°F (0 to -2°C) at the roller guides. This was not sufficient to interfere with mop operation. The rope mops did not freeze up at the test temperatures.

There was no evidence at the completion of testing of wringer scoring or other damage.

ROPE MOPS

The Foxtail rope mops are round in cross-section and attached to a central core of nylon webbing. Only the lower half of the mop contacts the oil while the remainder floats above the surface. A flat configuration with strands arranged on either side would likely be more efficient in contacting slicks and lead to higher oil content in thinner slicks.

Matting of the rope mops in higher viscosity oil lowered their efficiency. Neither tightening the rollers nor hot water improved wringing. The addition of a lid was discussed as a means of retaining heat when the spray nozzles are utilized but this might not result in significant heat transfer due to the short contact time with the mop. [A study undertaken by Environment Canada in 1977 of a large rope mop heater revealed that very high BTUs (and power) are required to yield modest improvements to the recovery of viscous oils.] A comb which separates the matted mop strands might provide a simpler solution.

POWER PACK & CONTROLS

The diesel/hydraulic power pack and control package were easy to operate. Starting was accomplished without difficulty as was prolonged operation. There were no mechanical problems nor repairs required during testing. A 15 minute warm-up period was needed for the skimmer to be able to be run at a constant speed, i.e. this allows the hydraulic oil to warm to its normal operating temperature. A bypass valve for hydraulic oil allows skimmer shutdown with continued powerpack operation. There is also supposed to be a compensator which permits pump operation without resulting in a variation in mop speed. (The pump was not operated during the tests.)

Adjustment of rope mop speed is made on a small console with a single control lever that is fixed in position with a wing nut. There is no scale nor readout and so mop travel had to be timed with a stop watch by following a taped segment as it passed through the skimmer. A mop speed readout could be incorporated to assist operator control.

PUMP

An axial screw pump is supplied as a separate part of the skimming package operated remotely from the skimming head. This has 5" (12.7 cm) ports which were converted on the discharge side to 6" Camlock fittings.

The placement and use of the pump are questionable. Discussions were held with the manufacturer on the possible incorporation of the pump in the skimming head sump. This would allow operation of the skimmer when the deck of the vessel serving as the working platform is above the skimmer. Otherwise, as it now exists, the skimmer gravity feeds to storage or the pump. The Alaska Clean Seas representative saw this as a potential problem for the operational configuration which that organization utilizes for oil recovery.

DEPLOYMENT

The attachment of the skimming unit to the crane was easily accomplished as was its deployment into the test area. Two guy ropes were used to ensure that the skimmer faced the desired direction so that the mops would travel downward to encounter the slick as the Foxtail was moved through the ice. The discharge hose then became the factor limiting the reach of the skimmer. The guy ropes, length of discharge hose and crane reach are all key factors in ensuring that the Foxtail can be safely and effectively deployed from a vessel. In this regard, it is also anticipated that the skimmer could not be deployed in higher sea states which could cause excessive movement.

7.0 CONCLUSIONS AND RECOMMENDATIONS

1. The Foxtail Skimmer comprises an oil recovery concept that has excellent potential and affords versatility for many oil-in-ice applications.
2. The diesel/hydraulic power pack operated without mechanical problems during the entire test period and appears to be a reliable package.
3. Skimmer performance is optimal at rope mop speeds of 0.75 to 1'/sec (0.2 -0.3 m/s) and in medium range viscosity oils. Mop length in the water appears to have less influence on Oil Recovery Rate. The unit is significantly less effective in diesel using the type of rope mop tested.
4. The Foxtail should be utilized in contained, concentrated slicks at least several inches thick (>4-5 cm) to operate effectively. Otherwise, the rope mops will pick up significant volumes of water upon contacting water below thin slicks. A flatter mop cross-section would improve Recovery Efficiency in such situations. Use of a 2 or 4 band Foxtail might also be considered.
5. The addition of hot water or steam nozzles is of questionable value. It did not augment skimmer performance. The use of a comb to separate matted rope mop strands should be considered.
5. Relocation of the pump to the sump in the puller/wringer should be considered to enable oil transfer from any vessel serving as the working platform.
6. Additional modifications should be reviewed including reconfiguration of the guide rollers and larger entry roller so that the wringing of liquid prior to entry into the wringer is reduced. A readout for mop speed and scale for the speed control lever should also be considered.
7. Pump and hydraulic connections should be specified so that these are compatible with all ancillary hardware associated with the skimmer's intended usage by the purchaser. Metals compatibility also requires review.
8. Deployment of a Foxtail from a vessel of opportunity requires preplanning of the crane required for suspending the skimming head, the length of discharge hose, the placement of guide ropes, and storage needs. The limitations of the unit for safe use in wave conditions also requires assessment.
9. Sea trials in broken ice should examine the ease of positioning the vessel and manoeuvring the mop in various ice forms so that entanglement does not occur. Associated logistical requirements should be thoroughly assessed (mainly liquid storage) as well as the condition of the mops in below-freezing temperatures. Utilization of a smaller 4-band unit should be considered for such tests in order to assess its capability in ice.



PLATE 1: TEST FACILITIES - TESORO REFINERY, KENAI, ALASKA

APPENDIX

DATE Dec 2, 1991

TIME 1350 hrs

TEST SERIES: BASELINE DATA - CRUDE OIL

Purpose oil wetting, system checkout, setup
Sample No. & Source 0 - baseline: oil from truck - not analyzed

AMBIENT CONDITIONS

Air Temperature 0°C
Water Temperature 0°C
Wind Speed & Direction 0-5 knots NE
Cloud Cover overcast
Precipitation 1425 light snow 1445 flurries

OIL

Type North Slope Crude (NSC)
Volume 110 gal
Slick Thickness 0.2" (5 mm)

ICE COVER 0 (2/10ths, slush at south end)

SKIMMER OPERATION

Rope Mop Speed variable
Rope Mop in Water variable
Run Time 70 minutes

LIQUID COLLECTED

Apparent Oil Phase not measured
Apparent Water Phase not measured

PERFORMANCE

Start-up OK, 40 minutes for adjustments
Deployment OK, guide ropes used to hold skimmer
Operation of Wringers OK
Product Transfer OK, pumps, fish totes arranged for collection

ADDITIONAL COMMENTS

Recovery Several minutes needed to oil rope mop.
Safety Skimming head secured.
Other Slippery around pit, oil splash minimized.
Slick remained on pit following skimming.
Air Monitoring % O₂ 20.8
LEL 0
H₂S 0.005 ppm
(measured by MSA II meter, calibrated with 10 ppm H₂S)

DATE Dec 3, 1991

TIME 1005 hrs

TEST SERIES A: OPEN WATER - CRUDE OIL

Purpose preliminary fresh crude tests
 Sample No. & Source A-1-0 crude from pit A-1-1 collected crude

AMBIENT CONDITIONS

Air Temperature -1°C
 Water Temperature 0°C
 Wind Speed & Direction 10 knots NE
 Cloud Cover overcast
 Precipitation none

OIL

Type North Slope Crude
 Volume 110 gal added
 Slick Thickness 0.2" (5 mm)

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed varied 2.1 - 1.25 ft/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 700 gal total liquid collected
 Apparent Water Phase not detected

RESULTS NOT REPORTED

	<u>A-1-0</u>	<u>A-1-1</u>
Specific Gravity	0.9225	0.9439
Viscosity	347 cSt	842 cSt
Pour Point	17°F (-8°C)	21°F (-6°C)
Water & Sediment	73.7%	38.2%

PERFORMANCE

Start-up OK, 45 minutes for test setup
 Deployment OK
 Operation of Wringers OK - see also below
 Product Transfer OK, pumps for distribution and transfer

ADDITIONAL COMMENTS

Recovery Mop speed slowed as hydraulic oil warmed up.
 Safety No safety problems are apparent.
 Other Water from mops and wringer is evident.
 Oil visibly thickened as test progressed.
 Small percentage of oil in collected fluid.
 Water layer not visible in collected emulsion.

DATE Dec 3, 1991

TIME 1200 hrs

TEST SERIES A: OPEN WATER - CRUDE OIL

Purpose aged crude test in open water
 Sample No. & Source A-2-0 crude from pit A-2-1 collected crude

AMBIENT CONDITIONS

Air Temperature -1°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation snow flurries

OIL

Type aged NSC from previous test
 Volume 110 gal added
 Slick Thickness 0.2" (5 mm)

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed 1'/sec after warmup
 Rope Mop in Water 6'
 Run Time 14 minutes

LIQUID COLLECTED

Apparent Oil Phase 400 gal total liquid = 237 gal oil = 16 gpm
 Apparent Water Phase not detected

	<u>A-2-0</u>	<u>A-2-1</u>
Specific Gravity	0.9306	0.9491
Viscosity	-	949 cSt
Pour Point	25°F (-4°C)	27°F (-3°C)
Water & Sediment	80.7%	41.7%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed is now held constant.
 Safety No problems are apparent.
 Other Liquid flowing from mops and wringer is evident.
 No oil is seen behind mops.
 Water layer not visible in collected emulsion.
 Corralled oil with sorbent boom.

DATE Dec 3, 1991

TIME 1400 hrs

TEST SERIES A: OPEN WATER - CRUDE OIL

Purpose aged crude test in open water
 Sample No. & Source A-3-0 crude from pit A-3-1 collected crude

AMBIENT CONDITIONS

Air Temperature -1°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation none

OIL

Type aged NSC from previous test
 Volume 110 gal
 Slick Thickness 0.2" (5 mm)

ICE COVER 0

SKIMMER OPERATION

Rope Mop Speed 1'/sec
 Rope Mop in Water 12'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 400 gal (100% oil collected) = 251 gal oil = 17 gpm oil
 Apparent Water Phase not detected

	<u>A-3-0</u>	<u>A-3-1</u>
Specific Gravity	0.9634	0.9613
Viscosity	905 cSt	931 cSt
Pour Point	27°F (-3°C)	25°F (-4°C)
Water & Sediment	90.1%	37.1%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed is held constant.
 Safety No problems are apparent.
 Other Liquid dropping from mops, wringer is evident.
 Oil is visible on water behind mops.
 Oil pickup is much quicker than previous test.
 Water layer not visible in collected emulsion.
 Recovered liquid has higher viscosity.
 Corralled oil with sorbent boom.

DATE Dec 3, 1991

TIME 1450 hrs

TEST SERIES A: OPEN WATER - CRUDE OIL

Purpose aged crude test in open water
 Sample No. & Source A-4-0 crude from pit A-4-1 collected crude

AMBIENT CONDITIONS

Air Temperature -1°C
 Water Temperature 0°C
 Wind Speed & Direction 5 - 10 knots NE
 Cloud Cover cloudy
 Precipitation none

OIL

Type aged NSC from previous test
 Volume 110 gal
 Slick Thickness 0.3" (7-8 mm), patchy

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 75 gal (50 - 100 gal) = 50 gal oil = 3.4 gpm oil
 Apparent Water Phase 275 gal based on in-line sample

	<u>A-4-0</u>	<u>A-4-1</u>
Specific Gravity	0.9596	0.9659
Viscosity	-	1,340 cSt
Pour Point	29°F (-2°C)	25°F (-4°C)
Water & Sediment	93.1%	32.8%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed is maintained constant.
 Safety No safety problems are apparent.
 Other Water from mops and wringer is very evident.
 Skimmer collects oil in first 5 minutes.
 Thin slick on 95% of pit. Estimate 10% of oil left on surface.
 Oil likely beginning to remain in hoses.
 Water layer not visible in collected emulsion.
 Corralled oil with sorbent boom.

DATE Dec 3, 1991

TIME 1550 hrs

TEST SERIES A: OPEN WATER - CRUDE OIL

Purpose aged crude test in open water
 Sample No. & Source A-5-0 crude from pit A-5-1 collected crude

AMBIENT CONDITIONS

Air Temperature 0°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation none

OIL

Type aged NSC from previous test
 Volume 110 gal
 Slick Thickness 0.3" (7-8 mm), patchy

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed 0.6'/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 20 gal (5-10% of collected liquid) = 11 gal = 0.7 gpm
 Apparent Water Phase 250 gal (90-95% of total liquid))

	<u>A-5-0</u>	<u>A-5-1</u>
Specific Gravity	-	0.9596
Viscosity	-	972 cSt
Pour Point	25°F (-4°C)	22°F (-6°C)
Water & Sediment	91.1%	44.5%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed constant.
 Safety No apparent safety problems.
 Other Mops mat with heavy oil which is much more viscous.
 Water from mops and wringer is evident.
 Slick remains on 20% of pit.
 Small percentage of oil in collected fluid.
 More oil lost in system (mops, hoses).
 Corralled oil with sorbent boom.

DATE Dec 3, 1991

TIME 1650 hrs

TEST SERIES B: OPEN WATER - CRUDE OIL

Purpose fresh crude test in open water
 Sample No. & Source B-1-0 crude from pit B-1-1 in-line sample from skimmer

AMBIENT CONDITIONS

Air Temperature 0°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation light snow

OIL

Type 95% fresh NSC
 Volume 200 gal
 Slick Thickness 0.4" (10 mm)

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed 1'/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 360 gal emulsn (90% tot liq) = 181 gal oil = 12 gpm oil
 Apparent Water Phase 40 gal (10% of collected liquid)

	<u>B-1-0</u>	<u>B-1-1</u>
Specific Gravity	0.8694	0.9329
Viscosity	324	299 cSt
Pour Point	-5°F (-11°C)	13°F (-11°C)
Water & Sediment	49.7%	49.0%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed is held constant.
 Safety No safety problems.
 Other Oil in pit is mostly fresh crude.
 Liquid falling from mops and wringer evident.
 Skimmer seemed to recover large % water.
 Corralled oil with sorbent boom.

DATE Dec 3, 1991

TIME 1730 hrs

TEST SERIES B: OPEN WATER - CRUDE OIL

Purpose fresh crude test in open water
 Sample No. & Source B-2-0 crude from pit B-2-1 in-line sample from skimmer

AMBIENT CONDITIONS

Air Temperature -1°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation light snow

OIL

Type fresh NSC
 Volume 200 gal
 Slick Thickness 0.4" (10 mm)

ICE COVER 0

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 350 gal total liquid phase = 207 gal = 14 gpm
 Apparent Water Phase emulsion collected

	<u>B-2-0</u>	<u>B-2-1</u>
Specific Gravity	0.9329	0.9163
Viscosity	313	286 cSt
Pour Point	0°F (-18°C)	13°F (-11°C)
Water & Sediment	19.6%	40.8%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wingers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed constant.
 Safety No safety problems are apparent.
 Other Oil in pit is mostly fresh crude.
 Mops are no longer matted.
 Water & oil falling from mops evident.
 Roller guide wrings oil prior to skimmer entry.
 Oil slick continues to exist after skimming.
 Corralled oil with sorbent boom.

DATE Dec 4, 1991

TIME 1200 hrs

TEST SERIES C: OPEN WATER - DIESEL

Purpose diesel test in open water
 Sample No. & Source C-1-0 from pit (50% water) C-1-1 collected (67% water)

AMBIENT CONDITIONS

Air Temperature 0°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover overcast
 Precipitation snow flurries

OIL

Type diesel
 Volume 110 gal added
 Slick Thickness 0.2" (5 mm)

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed 1'/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 25 gal (50% crude, 50% diesel) = 6 gal = 0.4 gpm
 Apparent Water Phase 25 gal

	<u>C-1-0</u>	<u>C-1-1</u>
Specific Gravity	0.8132	-
Viscosity	3.04 cSt	-
Pour Point	-60°F (-51°C)	-
Water & Sediment	48.5%	77.3%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed is held constant.
 Safety No problems are apparent.
 Other **1st test with decanting**
 Oil in pit is mostly diesel after cleaning.
 Mops become fluffy during run.
 Diesel appears to be cleaning mops.
 Water and oil falling from mops evident.
 Roller guide wrings oil prior to skimmer entry.
 Oil is now corralled with fabric boom.

DATE Dec 4, 1991

TIME 1425 hrs

TEST SERIES C: OPEN WATER - DIESEL

Purpose diesel test in open water
 Sample No. & Source C-2-0 diesel from pit (25% water) C-2-1 collected diesel

AMBIENT CONDITIONS

Air Temperature -2°C
 Water Temperature -1°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover overcast
 Precipitation light snow

OIL

Type diesel oil from previous test
 Volume 50 gal added from previous test
 Slick Thickness 0.3" (7-8 mm)

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 50 gal (50% diesel, crude) = 38 gal oil = 2.5 gpm
 Apparent Water Phase 50 gal

	<u>C-2-0</u>	<u>C-2-1</u>
Specific Gravity	-	-
Viscosity	-	-
Pour Point	-	-
Water & Sediment	84.2%	24.2%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed is held constant.
 Safety No problems are apparent.
 Other Oil in pit is mostly diesel after cleaning.
 Mops become fluffy during run.
 Water and oil falling from mops evident.
 Crude from mop is removed by diesel.
 Roller guide wrings oil prior to skimmer entry.
 Oil is corralled with fabric boom.

DATE Dec 4, 1991

TIME 1515 hrs

TEST SERIES C: OPEN WATER - DIESEL

Purpose diesel test in open water
Sample No. & Source no samples taken due to low volume recovered

AMBIENT CONDITIONS

Air Temperature 0°C
Water Temperature 0°C
Wind Speed & Direction 0 - 5 knots NE
Cloud Cover overcast
Precipitation no snow

OIL

Type diesel oil from previous test
Volume 100 gal from previous test
Slick Thickness 0.3" (7-8 mm)

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
Rope Mop in Water 18'
Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 10 - 20 gal <1 gpm oil
Apparent Water Phase 80 - 90 gal

PERFORMANCE

Start-up, Deployment, Transfer OK
Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed is held constant.
Safety No problems are apparent.
Other Oil in pit is mostly diesel.
Water & oil falling from mops evident.
Crude from mop is removed by diesel.
Roller guide wrings oil prior to skimmer entry.
Oil is corralled with fabric boom.

DATE Dec 4, 1991

TIME 1550 hrs

TEST SERIES C: OPEN WATER - DIESEL

Purpose diesel test in open water
 Sample No. & Source C-4-1 collected diesel

AMBIENT CONDITIONS

Air Temperature -1°C
 Water Temperature -1°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover partly cloudy
 Precipitation no snow

OIL

Type diesel oil from previous test
 Volume 100 gal from previous test
 Slick Thickness 0.3" (7-8 mm)

ICE COVER

0

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
 Rope Mop in Water 18'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 40 gal (50% diesel, crude) = 14 gal oil = 1.0 gpm oil
 Apparent Water Phase 110 gal
 Specific Gravity 0.8293
 Viscosity 4.58 cSt
 Pour Point -60°F (-51°C)
 Water & Sediment 64.2%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below
 Product Transfer OK

ADDITIONAL COMMENTS

Recovery Mop speed constant.
 Safety No problems are apparent.
 Other Mops are fluffy - excellent for oil pickup.
 Oil in pit is mostly diesel.
 Oil (losses) falling from mops still evident.
 Ice builds up at guide rollers.
 Roller guide wrings oil prior to skimmer entry; liquid losses high.
 Path clear of oil on water between mop travel.
 Oil is corralled with fabric boom.

DATE Dec 5, 1991

TIME 0930 hrs

TEST SERIES D: ICE COVER - CRUDE OIL

Purpose fresh crude test in ice
Sample No. & Source D-1-1 collected oil

AMBIENT CONDITIONS

Air Temperature 0°C
Water Temperature 0°C
Wind Speed & Direction 5 - 10 knots NE
Cloud Cover cloudy
Precipitation snow flurries

OIL

Type fresh crude
Volume 200 gal added
Slick Thickness 0.4" (mm)

ICE COVER 4/10ths

SKIMMER OPERATION

Rope Mop Speed 1'/sec
Rope Mop in Water 6'
Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 80 gal = 45 gal oil = 3.0 gpm oil
Apparent Water Phase 70 gal
Specific Gravity 0.8359
Viscosity 6.94 cSt
Pour Point -60°F (-51°C)
Water & Sediment 44.1%

PERFORMANCE

Start-up, Deployment, Transfer OK
Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Mop speed constant, skimmer held stationary.
Safety No problems are apparent.
Other Test oil is fresh crude.
Oil (losses) falling from mops still evident.
Mops fold over on ice cover.
Roller guide wrings oil prior to skimmer entry.

DATE Dec 5, 1991

TIME 1125 hrs

TEST SERIES D: ICE COVER - CRUDE OIL

Purpose fresh crude test in ice
Sample No. & Source D-2-1 oil collected

AMBIENT CONDITIONS

Air Temperature 0°C
Water Temperature 0°C
Wind Speed & Direction 5 - 10 knots NE
Cloud Cover cloudy
Precipitation snow flurries

OIL

Type fresh crude plus some aged crude
Volume 50 gal fresh crude added
Slick Thickness 0.4 - 0.8" (10 - 20 mm)

ICE COVER 4/10ths

SKIMMER OPERATION

Rope Mop Speed 1'/sec
Rope Mop in Water 18'
Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 200 gal = 79 gal oil = 5.3 gpm
Apparent Water Phase 120 gal
Specific Gravity 0.8999
Viscosity 179 cSt
Pour Point 1°F (-17°C)
Water & Sediment 60.5%

PERFORMANCE

Start-up, Deployment, Transfer OK
Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Skimmer is now swept through ice.
Safety No problems are apparent.
Other Test oil is mostly fresh plus some aged crude.
Oil (losses) falling from mops still evident.
Mops travel on and between ice cover.
Roller guide wrings oil prior to skimmer entry.

DATE Dec 5, 1991

TIME 1330 hrs

TEST SERIES D: ICE COVER - CRUDE OIL

Purpose fresh crude test in ice
Sample No. & Source D-3-1 oil collected

AMBIENT CONDITIONS

Air Temperature 1°C
Water Temperature 0.5°C
Wind Speed & Direction 0 - 5 knots NE
Cloud Cover cloudy
Precipitation snow

OIL

Type primarily fresh crude
Volume 150 gal fresh crude added
Slick Thickness 0.4" (10 mm)

ICE COVER

4/10ths

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
Rope Mop in Water 18'
Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 125 gal = 64 gal oil = 4.3 gpm oil
Apparent Water Phase 125 gal
Specific Gravity 0.9067
Viscosity 316 cSt
Pour Point 10°F (-12°C)
Water & Sediment 48.7%

PERFORMANCE

Start-up, Deployment, Transfer OK
Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Skimmer is swept though ice.
Safety No problems are apparent.
Other Test oil is mainly fresh with some aged crude.
Wringer mechanism is tightened.
Oil (losses) falling from mops still evident.
Mops travel on and between ice cover.
Mop folds back on itself.
Mop pushes large amount of ice as it travels.
Ice also being cleaned of oil.
Roller guide wrings oil prior to skimmer entry.

DATE Dec 5, 1991

TIME 1415 hrs

TEST SERIES D: ICE COVER - CRUDE OIL

Purpose fresh crude test in ice
 Sample No. & Source D-4-1 oil collected

AMBIENT CONDITIONS

Air Temperature 1°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation snow

OIL

Type aged plus fresh crude
 Volume 150 gal fresh crude added
 Slick Thickness 0.4" (10 mm)

ICE COVER

4/10ths

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 50 gal = 22 gal oil = 1.5 gpm oil
 Apparent Water Phase 150 gal
 Specific Gravity 0.9117
 Viscosity 421 cSt
 Pour Point 12°F (-11°C)
 Water & Sediment 55.6%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Skimmer is swept through ice.
 Safety No problems are apparent.
 Other Oil in pit is mostly fresh and some aged crude.
 Mops travel on and between ice cover.
 Mop pushes less ice than previous run.
 Oil appears to be picked up but:
 Mop still folds back on itself.
 Oil (losses) falling from mops still evident.
 Roller guide wrings oil prior to skimmer entry.

DATE Dec 5, 1991

TIME 1555 hrs

TEST SERIES D: ICE COVER - CRUDE OIL

Purpose aged crude test in ice
 Sample No. & Source D-5-0 oil in pit D-5-1 oil collected

AMBIENT CONDITIONS

Air Temperature 0°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation snow

OIL

Type aged crude
 Volume 170 gal aged crude added
 Slick Thickness 0.4" (10 mm)

ICE COVER 4/10ths

SKIMMER OPERATION

Rope Mop Speed 1'/sec
 Rope Mop in Water 18'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 170 gal = 57 gal oil = 3.8 gpm
 Apparent Water Phase 280 gal

	<u>D-5-0</u>	<u>D-5-1</u>
Specific Gravity	0.9177	0.9247
Viscosity	570 cSt	1,111 cSt
Pour Point	13°F (-11°C)	15°F (-9°C)
Water & Sediment	25%	66.7%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Skimmer is swept through oil and ice.
 Safety No problems are apparent.
 Other Oil in pit is aged crude from Days 1-4.
 Oil (losses) falling from mops still evident.
 Mops travel on and between ice cover.
 Mop still folds back on itself.
 Roller guide wrings oil prior to skimmer entry.
 Appears to be best run in ice.

DATE Dec 5, 1991

TIME 1700 hrs

TEST SERIES D: ICE COVER - CRUDE OIL

Purpose aged crude in ice, steam added
 Sample No. & Source D-6-1 oil collected

AMBIENT CONDITIONS

Air Temperature 0°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation snow

OIL

Type aged crude
 Volume 80-90 gal aged crude added
 Slick Thickness 0.4" (10 mm)

ICE COVER

4/10ths

SKIMMER OPERATION

Rope Mop Speed 1'/sec
 Rope Mop in Water 18'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 120 gal = 54 gal oil = 3.6 gpm oil
 Apparent Water Phase 400 gal
 Specific Gravity 0.9327
 Viscosity 851 cSt
 Pour Point 17°F (-8°C)
 Water & Sediment 54.9%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Skimmer is swept through ice.
 Safety No problems are apparent.
 Other Oil in pit is aged crude from Days 1-4.
 "Steam": 750 psi, 150°F, 7 gpm
 Oil (losses) falling from mops still evident.
 Mops travel on and between ice cover.
 Mop still folds back on itself.
 Roller guide wrings oil prior to skimmer entry.
 Steam adds water to collected liquid (100 gal).
 Slight fluffing of mop is seen.

DATE Dec 6, 1991

TIME 0930 hrs

TEST SERIES E: ICE COVER - CRUDE OIL

Purpose aged crude in ice
 Sample No. & Source E-0-1 oil in pit E-1-1 oil collected

AMBIENT CONDITIONS

Air Temperature 0°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation snow

OIL

Type aged crude
 Volume 200 gal aged crude in pit
 Slick Thickness 0.4" (10 mm)

ICE COVER

4/10ths

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
 Rope Mop in Water 18'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 100 gal = 41 gal oil = 2.7 gpm oil
 Apparent Water Phase 170 gal

	<u>E-1-0</u>	<u>E-1-1</u>
Specific Gravity	0.9607	0.9377
Viscosity	1,929 cSt	944 cSt
Pour Point	23°F (-5°C)	20°F (-7°C)
Water & Sediment	82.4%	59.0%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Skimmer is swept through ice.
 Safety No problems are apparent.
 Other Oil in pit is aged crude from Days 1-4.
 Oil (losses) falling from mops still evident.
 Mops travel on and between ice cover.
 Roller guide wrings oil prior to skimmer entry.
 Emulsion is visibly thickening.
 Snow accumulates on ice.
 Skimmer appears to work well.

DATE Dec 6, 1991

TIME 1030 hrs

TEST SERIES E: ICE COVER - CRUDE OIL

Purpose aged crude test in ice with steam
 Sample No. & Source E-2-1 collected oil: emulsion phase

AMBIENT CONDITIONS

Air Temperature 1°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation snow

OIL

Type aged crude
 Volume 200 gal aged crude in pit
 Slick Thickness 0.4" (10 mm)

ICE COVER 4/10ths

SKIMMER OPERATION

Rope Mop Speed 0.75'/sec
 Rope Mop in Water 18'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 110 gal = 69 gal oil = 4.6 gpm oil
 Apparent Water Phase 440 gal
 Specific Gravity 0.9457
 Viscosity 950 cSt
 Pour Point 20°F (-7°C)
 Water & Sediment 37.5%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wringers OK - see also below

ADDITIONAL COMMENTS

Recovery Skimmer is swept through oil and ice.
 Safety No problems.
 Other Oil in pit is aged crude from Days 1-4.
 1 nozzle blocked on steam arm; repairs tried.
 Collected liquid includes steam during repair.
 Oil (losses) falling from mops still evident.
 Mops travel on and between ice cover.
 Roller guide wrings oil prior to skimmer entry.
 Emulsion is visibly thickening.

(This page left intentionally blank)

DATE Dec 6, 1991

TIME 1130 hrs

TEST SERIES E: ICE COVER - CRUDE OIL

Purpose aged crude test in ice without steam
 Sample No. & Source E-3-1 collected oil

AMBIENT CONDITIONS

Air Temperature 0°C
 Water Temperature 0°C
 Wind Speed & Direction 0 - 5 knots NE
 Cloud Cover cloudy
 Precipitation snow

OIL

Type aged crude
 Volume 200 gal aged crude in pit
 Slick Thickness 0.4" (10 mm)

ICE COVER 4/10ths

SKIMMER OPERATION

Rope Mop Speed 1'/sec
 Rope Mop in Water 6'
 Run Time 15 minutes

LIQUID COLLECTED

Apparent Oil Phase 200 gal = 84 gal oil = 5.6 gpm oil
 Apparent Water Phase 220 gal
 Specific Gravity 0.9497
 Viscosity 1,469 cSt
 Pour Point 25°F (-4°C)
 Water & Sediment 58.0%

PERFORMANCE

Start-up, Deployment, Transfer OK
 Operation of Wingers OK - see also below
 Product Transfer OK

ADDITIONAL COMMENTS

Recovery Skimmer is swept through oil and ice.
 Safety No apparent problems.
 Other Oil in pit is aged crude from Days 1-4.
 Tried "walking" mops across oil and ice, i.e matching rate of advance
 with mop travel.
 Oil (losses) falling from mops still evident.
 Mops travel on and between ice cover.
 Roller guide wingers oil prior to skimmer entry.
 Skimmer moves ice as it travels.